3-1968

The Ecology of Pieris floribunda Benth. and Hook., an Ericad, in a Pine-Heath Community in the Great Smoky Mountains

Caroline Triplett Wingfield
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Caroline Triplett Wingfield entitled "The Ecology of Pieris floribunda Benth. and Hook., an Ericad, in a Pine-Heath Community in the Great Smoky Mountains." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Botany.

Edward E.C. Clebsch, Major Professor

We have read this thesis and recommend its acceptance:

H.R. DeSelm, James D. Caponetti

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

December 15, 1967

To the Graduate Council:

I am submitting herewith a thesis written by Caroline Triplett Wingfield entitled "The Ecology of *Pieris floribunda* Benth. and Hook., an Ericad, in a Pine-Heath Community in the Great Smoky Mountains." I recommend that it be accepted for eighteen quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Botany.

Edward E.C. Clebsch
Major Professor

We have read this thesis and recommend its acceptance:

H. R. DeSelm

James D. Caponetti

Accepted for the Council:

Hilton A. Smith
Vice President for
Graduate Studies and Research

THE ECOLOGY OF *PIERIS FLORIBUNDA* BENTH. AND HOOK., AN ERICAD, IN A PINE-HEATH COMMUNITY IN THE GREAT SMOKY MOUNTAINS

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Caroline Triplett Wingfield

March 1968

ACKNOWLEDGEMENTS

The author wishes to express sincere appreciation to the other graduate students in the Botany Department for their advice and criticism of the thesis and for their assistance in completing the field work.

Special thanks are extended to my father, Dr. Harvey N. Wingfield, Jr. and Mr. M. D. Kerby, Jr. for the chemical analysis of the soil samples.

For identification of the lichens in the study area, the author wishes to thank Mr. Isao Yoshimura.

The author is grateful to her major professor, Dr. Edward E. C. Clebsch, and also to Dr. H. R. DeSelm and Dr. James D. Caponetti for their criticism of the thesis.

The help extended to the author by the staff of the Great Smoky Mountains National Park is greatly appreciated. Travel necessary for this study was partially supported through contract No. 14-10-0117-634 between the National Park Service and The University of Tennessee. This assistance is gratefully acknowledged.

TABLE OF CONTENTS

SECTION	PAGE
I. INTRODUCTION	1
Objectives	1
The Study Area	1
Vegetational Studies	9
II. METHODS	15
III. RESULTS	19
Frequency of Trees	19
Density and Basal Area of Trees	21
Frequency and Density of Shrubs	25
Herbaceous Cover	25
Pieris floribunda	27
Environmental Study	29
IV. DISCUSSION AND CONCLUSIONS	43
V. SUMMARY	48
LITERATURE CITED	50
APPENDIXES	54
A. PROCEDURE FOR THE PREPARATION OF SOIL SAMPLES	55
B. SUMMARY OF TREE TAXA IN DIAMETER CLASSES BY PLOT	57
C. SUMMARY OF SHRUB TAXA IN DIAMETER CLASSES BY PLOT	65

LIST OF TABLES

TABLE PAGE

I. Per Cent Frequency of Tree Species in the Tree Stratum, Under One Inch Diameter and As Seedlings. 20

II. Mean Density Per Plot and Per Cent Total Basal Area of Trees in the Study Area 22

III. Species Present and Their Frequency in the Herbaceous Cover . 26

IV. The Mean, Standard Deviation and Range of Several Characters of _Pieris_ _floribunda_ 28

V. Values of Components of Regression Equations of Temperatures. 37

VI. Soil Profiles and pH Values from the Bullhead Trail Pine-Heath and a Pine-Heath at 2800 Feet Elevation Studied by McGinnis 40

VII. Available Cations of Soils in the Study Area. 41

LIST OF FIGURES

FIGURE PAGE

1. Reproductive Structures of Pieris floribunda, Benth. and Hook. (a) Flower, X5; (b) Capsule, X4; (c) Seed, 10X (from Wood, C. E., 1961) 4
2. World Distribution of the Genus Pieris (from Li, Hi-Lin, 1952) 5
3. Pieris floribunda Growing Along Blue Ridge Parkway Near Mt. Pisgah, North Carolina (Spring, 1967) 7
4. Bullhead Trail in Study Area (Fall, 1966) 10
5. Aerial Photograph of Bullhead Trail in the Vicinity of the Study Area 16
6. A Comparison of Diameter Distribution of All Stems in Two Pine-Heath Stands: the Study Area and a Stand Investigated by Whittaker (1956) 23
7. (a) Pinus pungens in Pine-Heath Community Studied by Whittaker (1956). (b) P. pungens in Study Area 24
8. Average Maximum Temperatures for Five Stations in Study Area for the One Foot Level, Litter, and Soil 30
9. Average Minimum Temperatures for Five Stations in Study Area for the One Foot Level, Litter, and Soil 31
10. Comparison of Average Maximum Temperatures for Three Areas in Great Smoky Mountains National Park: Park Headquarters, Study Area, and Newfound Gap 33

FIGURE PAGE

11. Comparison of Average Minimum Temperatures for Three Areas in Great Smoky Mountains National Park: Park Headquarters, Study Area, and Newfound Gap 34

12. Relation of Newfound Gap and Study Area Maximum (a) and Minimum (b) Temperatures 35

13. Relation of Park Headquarters and Study Area Maximum (a) and Minimum (b) Temperatures 36

14. A Comparison of the Cumulative Rainfall for Three Locations in Great Smoky Mountains National Park: Newfound Gap, Study Area, and Park Headquarters. 39

I. INTRODUCTION

Objectives

A member of the heath family, Ericaceae, *Pieris floribunda* Benth. and Hook. is endemic to the Southern Appalachian Mountains, its distribution being concentrated in the higher elevations of the Great Smoky Mountains National Park.

For many years these small shrubs have been noted growing beside the trails in the Park in some of the most xeric habitats, especially pine-heath communities, along with other ericaceous plants. By close examination of the climatology, soils and associated vegetation of these habitats, it was hoped that some clues might be found as to what factors allow *P. floribunda* to survive and reproduce in these xeric habitats. Through investigation of the above and certain aspects of the autecology of *Pieris*, the vegetational role of this heath shrub in this particular community might be clarified.

The Study Area

The Great Smoky Mountains of western North Carolina and eastern Tennessee are an area of great environmental and vegetational diversity. Mt. LeConte, with a peak elevation of 6593 feet, is one of the highest mountains in the region. Located on its western slope is the Bullhead, the site of this study.

Whittaker (1956) describes fifteen vegetation types as being present in the Great Smoky Mountains National Park. The majority of these would be encountered on ascending Mt. LeConte. The pine-heaths, with which this paper is concerned, are characterized by pine woods with a dense understory of heath shrubs. They are most frequent on southern exposures between 3000 and 4000 feet in elevation. These pine-heaths occur predominantly on ridges and may extend from the cove hardwood zone to the very lower limits of the spruce-fir zone. Such a wide distribution is to be seen on the Bullhead Trail. The topographic distribution of these pine-heaths is comparable to that of the heath balds, but at a lower elevation than these (Cain, 1931a).

The parent rocks of most of the soils of the Great Smoky Mountains are quartzites, slates and sandstones (Hadley and Goldsmith, 1963). Generally, the soils are acid with the greatest acidity occurring in the highest elevations and most exposed sites (Whittaker, 1956). Cain (1931b) found that a pine-heath at 3400 feet elevation in the Great Smoky Mountains had an average soil depth of six inches and an average pH of 4.9 for the surface soils with a range from 5.6 to 4.1, and an average pH of 5.0 for the subsoil with a range of 5.8 to 4.5.

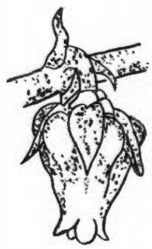
The climate of a pine-heath at an elevation of 4000 feet falls within the perhumid class of the Thornthwaite (1948) climatic classification. Precipitation at this elevation is between 78 inches and 89 inches per year, based on a five year mean (Shanks, 1954). According to Tanner (1963), the isotherms of daily maxima on north-facing slopes follow the altitudinal contour lines. However, on south-facing slopes, the isotherms are perpendicular to the contours. For example, a ridge extending down a mountainside which would probably be occupied by a pine-heath or heath bald, would have an isotherm connecting its upper and lower limits.

Pieris

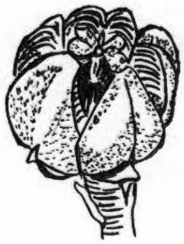
The nomenclature of the species of *Pieris* follows that found in Bailey (1930). Palser (1952) discussed the various characters employed to delimit the larger plant groups in the Ericales, especially the megasporogenesis and the development of the megagametophyte in the Andromedeae.

The entire genus may be characterized by the following: the ". . . leaves alternate, short petioled, entire or serrulate: flowers in often panicled racemes; calyx-lobes valvate or distinct; stamens ten; anthers obtuse, with a pair of awns near the base or the filaments two-toothed below the apex: capsules with five dehiscent valves; seeds linear-oblong, not winged, with membranous testa" (Bailey, 1930). Figure 1 illustrates the typical flower, fruit and seed of *Pieris floribunda*.

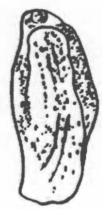
The genus *Pieris* is quite diversified in many respects, being both deciduous and evergreen, varying from small shrubs to trees 40 feet in height and with a geographical range with one center in eastern Asia and the other in the eastern half of the United States. In the United States, *Pieris*' range extends from West Virginia, western Virginia, western North Carolina, to eastern Tennessee, and northern Georgia. The world distribution of *Pieris* is shown in Figure 2.



(a)



(b)



(c)

Figure 1. Reproductive structures of *Pieris floribunda*, Benth. and Hook. (a) Flower, X5; (b) capsule, X4; (c) seed, X10 (from Wood, C. E., 1961).

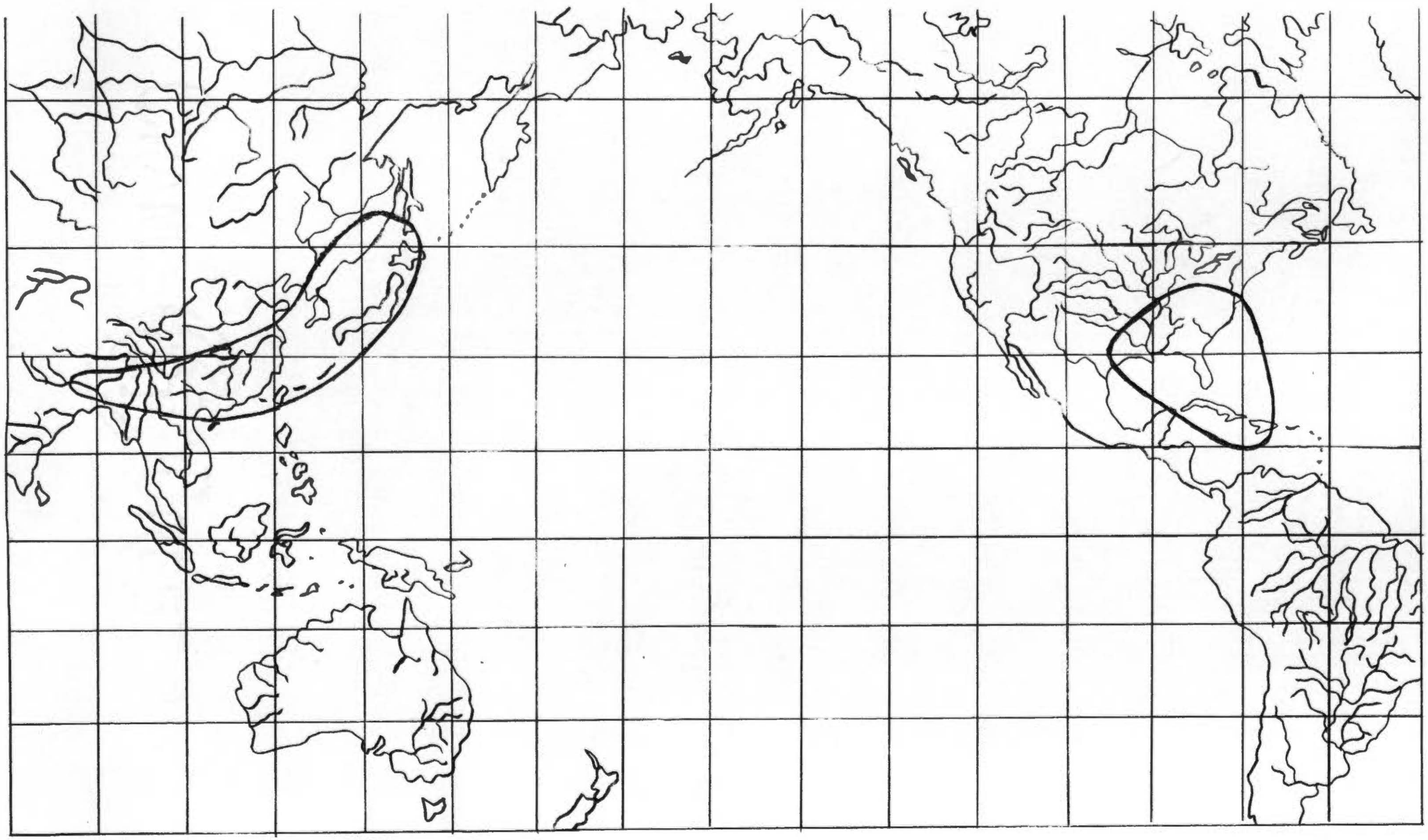


Figure 2. World distribution of the genus _Pieris_ (from Li, Hui-Lin, 1952).

Pieris floribunda is considered as endemic to the Unaka range of eastern Tennessee and western North Carolina, with its distribution centering in the Great Smoky Mountains (Cain, 1930). Whittaker (1956) found that the distribution of *P. floribunda* in the Smokies centered in xeric sites and at times extended into subxeric and submesic ones. Usually *P. floribunda* is limited to elevations above 4000 feet in the Smokies, but scattered plants have been seen along the Bullhead Trail extending as low as 3000 feet in elevation. Along the Blue Ridge Parkway in North Carolina, *P. floribunda* occurs at lower elevations as is seen in Figure 3.

Pieris is cultivated as an ornamental shrub in many locations; *P. floribunda* and *P. mariana* are used in the northern United States where they are valued for the earliness of their flowers. *P. japonica*, which was introduced from Japan, and *P. formosa*, from the Eastern Himalayas, are considered the most beautiful. *P. formosa* is restricted to the southern regions of the United States while *P. japonica* may appear as far north as Massachusetts, but in that environment, the flowers are usually winter killed (Bailey, 1930).

The migration and evolution of the Andromedeae in North America has been considered by Lems (1962). Height growth in the Andromedeae is achieved by a succession of lateral buds since the terminal shoot meristem has a limited life span. The sequence of a "morphogenetic cycle" includes the following: (1) early bud growth, with development of scale leaves; (2) growth of leafy shoots; (3) inflorescence formation and formation of the flower buds; (4) meiosis, pollen and ovule

Figure 3. <u>Pieris</u> <u>floribunda</u> growing along Blue Ridge Parkway near Mt. Pisgah, North Carolina (spring, 1967).

maturation; (5) flower opening, subsequent pollination, and fertilization; (6) fruit maturation; and (7) dehiscence of fruit and seed dispersal. The time of interruption of this sequence by dormancy is the criterion Lems utilizes to distinguish three main types of development in North America among the Andromedeae.

The cycle of *Pieris* is as follows. In May and June new lateral shoots are produced and by August the leaves are mature and the inflorescences have formed (Lems, 1962). The anthers over winter in the microspore mother-cell stage. These reach the tetrad stage before the ovules have developed further than the megaspore mother-cell stage (Palser, 1951). Flowering occurs in the following spring even though meiosis occurred in the previous July and August. Maturation of the fruit usually is by July. Over wintering in this condition may also indicate the tropical origin of these species where flower dormancy became a means of survival upon migration.

The one-season cycle, in which the whole reproductive cycle is completed in one year, is said to be the best adaptation to the alternation of summer and winter seasons. *Oxydendrum* exhibits such a cycle. Other members of the Andromedeae from South and Central America (*e.g.*, *Lyonia*) need two complete growing seasons for one "morphological cycle," and Lems (1962) speculates that as these tropical Andromedeae migrated northward, surviving the winter season was accomplished thusly: acceleration of the cycle, dormancy of flowers, and delay of inflorescence formation. For *Pieris floribunda*, survival seems to have been accomplished by dormancy of the flowers (Lems, 1962).

Vegetational Studies

It has been noted by Whittaker (1956) that most mature pine stands in the Great Smoky Mountains are of mixed species while immature ones are usually single-species stands. The picture in Figure 4 was taken from the trail in the Bullhead pine-heath where the stand is predominantly Pinus pungens.[1]

According to Cain (1937) fire is the leading factor in the maintenance of pine-heaths. As deciduous trees make their appearance here, it can be seen that as they increased in number, the pines would decrease and finally be eliminated. Therefore, the pine-heath is most likely a transitory stage. However, since its duration may be more than a century and may be perpetuated at times by fires, Cain considers it an edaphic or topographic climax.

Whittaker (1956) distinguishes two pine-heath communities in the Smokies on the basis of their dominants: pitch pine (Pinus rigida) and table mountain pine (P. pungens). The pitch pine heath is usually found between the elevations of 2200 to 3200 feet. Quercus coccinea is usually present and at times may share dominance with the pine. Q. prinus and Castanea dentata are almost always present along with Acer rubrum and Oxydendrum arboreum. Shrub coverage ranges from 40 to 70 per cent and the herbaceous cover usually ranges from 5 to 20 per cent. Kalmia latifolia and Vaccinium vacillans or V. hirsutum usually dominate the shrub stratum with Andropogon scoparius, Pteridium

---

[1]Nomenclature follows that of Fernald (1950).

Figure 4. Bullhead Trail in study area (fall, 1966).

aquilinum var. latisculum, Epigaea repens, Gaultheria procumbens dominating the herbaceous layer. The table mountain pine-heath occurs toward the upper limits of the pine-heaths. At these higher elevations, they are characterized by low stature and density. The most prevalent species in the tree stratum after Pinus pungens are P. rigida, Quercus coccinea, Q. prinus, Castanea dentata, Nyssa sylvatica, Acer rubrum, Oxydendrum arboreum, Robinia pseudo-acacia, and Sassafras albidum. Kalmia latifolia and the Vaccinioideae are the dominants of the shrub stratum with a total shrub cover of 60 to 90 per cent. Whittaker states that Pieris floribunda may be a dominant at the higher elevations. Galax aphylla, Epigaea repens and Gaultheria procumbens are the major species in the herbaceous layer with a coverage of only 5 to 20 per cent.

Whittaker (1966) found that the above-ground net annual production is 420-650 g./m.^{2} for forest heaths of xeric slopes and forests of highest elevations as compared to 1000-1200 g./m.^{2} for mature climax forests of mesic environments. He also found that shrub production is usually higher in xeric environments, being 20-145 per cent of tree production in forest heaths.

In the southeastern portion of the Blue Ridge Escarpment, a study was conducted by Racine (1966) of pine ridge communities. He found a two to three inch immature mor humus layer composed of a litter and fermentation zone but lacking the humus zone. The soil itself is characterized by low nutrient content, the calcium concentration never exceeding 50 p.p.m. and potassium never above 80 p.p.m.

Racine (1966) describes two community types for these ridges, the pine community and the pine-oak community. The pine community was found to occupy the driest ridges with scattered individuals of *Quercus coccinea*, *Nyssa sylvatica*, *Quercus prinus* and *Acer rubrum*. A heath of *Kalmia latifolia* or *Vaccinium vacillans* may occur in patches. The pine-oak community is characteristic of less xeric ridges. There is a higher proportion of oaks in comparison to pines and the heath is much more prevalent. This community seems to be more closely related to the pine-heaths of the Great Smoky Mountains than the pine community. Cooper (1963) and Rodgers (1965) found this same relationship to be true of other pine communities in North Carolina which they investigated.

Williams and Oosting (1944) in a study of the vegetation of Pilot Mountain, North Carolina, found *Pieris floribunda* to be the dominant shrub species occurring with *Kalmia latifolia*, *Rhododendrum catawbiense*, *Smilax rotundifolia*, and *Vaccinium corymbosum* var. *pallidum*. Pilot Mountain is in the northwestern Piedmont of North Carolina and is isolated from the Blue Ridge. The peak elevation is approximately 2000 feet. *Pinus pungens*, *P. rigida*, *Oxydendrum arboreum*, *Nyssa sylvatica*, *Acer rubrum*, *Quercus borealis* var. *maxima* and *Robinia pseudo-acacia* constitute the tree stratum. All factors except altitude correspond to what Cain (1931a) refers to as sub-climax pine-heaths in the Great Smoky Mountains.

In a study of the vascular flora of the Southern Appalachians, Ramseur (1960) found *Pieris* to be present in three different communities: in a heath bald in the Plott Balsam Mountains, a shrub bald on the Pisgah Ridge and in the fire cherry, grassy bald, heath bald, and shrub bald communities in the Balsam Mountains. He distinguishes the shrub bald from the heath bald in that species of shrubby trees usually found at lower altitudes are prevalent in the shrub bald.

Davis (1930) classifies the vegetation of the Black Mountains of North Carolina into three formations, the spruce-fir forest, the northern hardwood forest and the Appalachian forest. He further subdivides the Appalachian forest formation into three minor communities, the cove climax, the mesic slope, and the xeric slope and ridge associations.

The cove climax association is composed of southern hardwood species and characteristically has an understory of heath shrubs. It is difficult at times to distinguish between the cove climax association and the mesic slope association. The mesic slope association was also found to intergrade into the xeric slope and ridge association at its upper limits. However, this association is set off from the other two because of the scarcity of hemlocks and pines and the abundance of oaks. An understory of heath shrubs is present here also. The xeric slope and ridge association is limited to the dry slopes and ridges and is characterized by the dominance of pines and a few oaks. The pines may often form pure stands. The understory of heath is present and may be extremely abundant at times.

Davis found *Pieris floribunda* with a moderate percentage of frequency or abundance in the mesic slope association and to be both this and locally abundant as a consociation or clan in the xeric slope and ridge association.

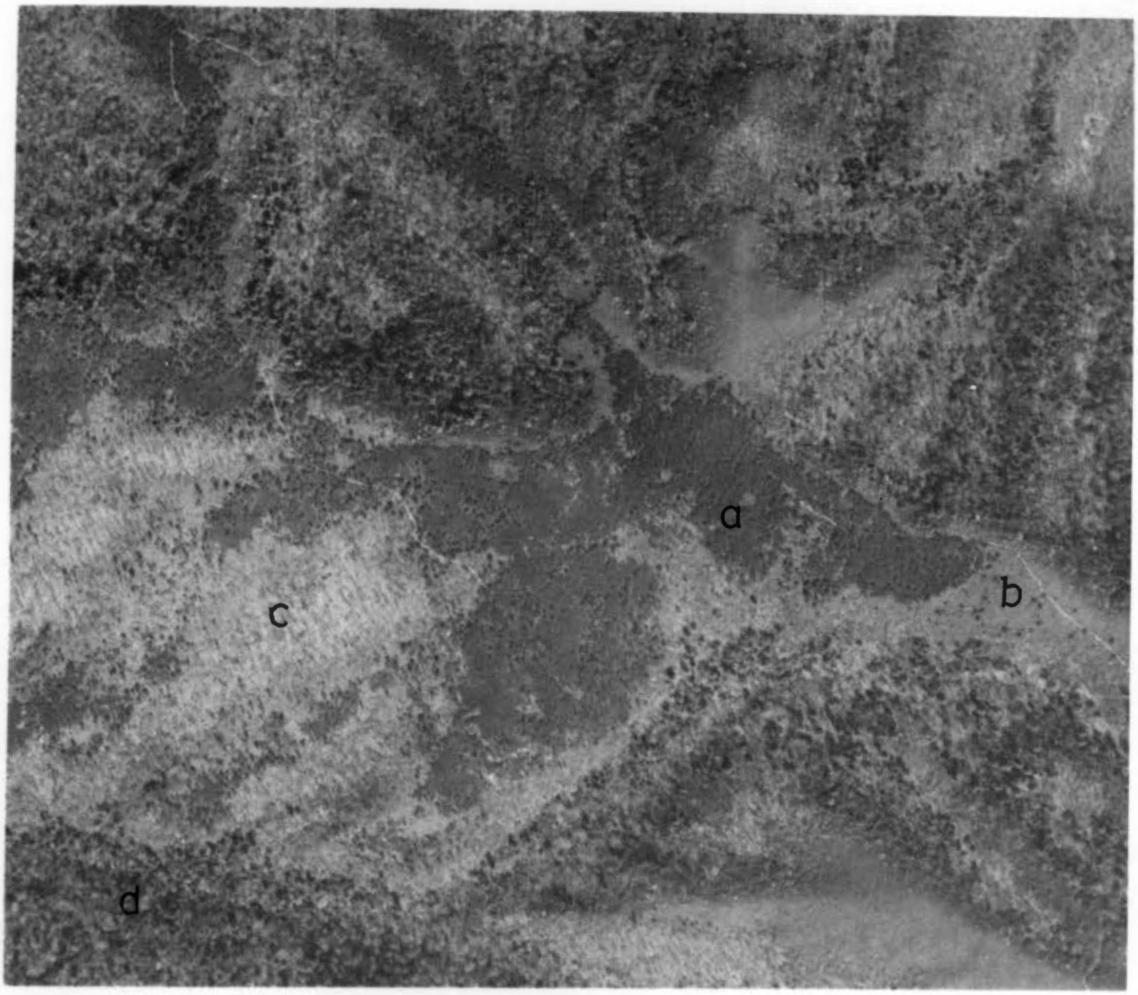
II. METHODS

Specimens of _Pieris_ from herbaria in the Great Smoky Mountains region were examined and the collection sites noted. From this, a list was compiled of locations of _Pieris floribunda_ within the Great Smoky Mountains National Park and these locations were visited. The pine-heath community traversed by the Bullhead Trail, Mt. LeConte, was chosen from all the others for the study area because of its large size and the abundance of _Pieris_. It is located approximately two and one half miles east of Cherokee Orchard.

The Bullhead Trail in the study area extends from 4110 feet to 4250 feet elevation. The pine-heath itself lies on a south-facing slope, extending from the top of the ridge to varying distances down slope as can be seen in the aerial photograph of the area in Figure 5. At its upper boundary along the trail, the pine-heath merges with a heath bald.

A total of forty sets of nested square plots was established in a line parallel to the Bullhead Trail. A compass was used to make adjacent plot edges parallel. Plots were spaced 50 feet apart.

Twenty of the plots were established in disturbed trail edge vegetation to test its effect on _Pieris_ density. They were placed adjacent to and with one edge on the trail. A table of random numbers was used to determine on which side of the trail to place them. The larger plots were .05 acre (46 feet, 8 inches on a side) with .02 acre (31 feet, 7.5 inches on a side) and .01 acre (20 feet, 10.5 inches on



a. Study area
b. Heath bald
c. Open oak
d. Cove hardwood

Figure 5. Aerial photograph of Bullhead Trail in the vicinity of the study area.

Source: TVA aerial photograph AOB-15L-91, April 19, 1954.

a side) plots placed in one corner of each of the .05 acre plots. The second twenty sets of plots of this same description were placed at distances greater than 50 feet from the trail. A table of random numbers was used to determine the distance and direction (up or down slope) from the trail. A clinometer was used to determine the slope of each plot and the length of the sides was adjusted accordingly.

Within each .05 acre plot, the d.b.h. (diameter at breast height) of each tree was measured and its height estimated. The .02 acre plot was used originally to measure the diameter of the shrub layer (at one foot from ground surface). Because of the uniformity of the shrub layer, its sampling size was diminished to .01 acre. The diameter of the largest stem, the total number of stems, and the maximum height of each shrub was recorded. Because of the nature of the shrub layer, a smaller plot, one-half the area of the .01 acre plot, was designated to measure the diameter of every stem present. All vascular taxa present were listed and the percentage ground cover was estimated for the herbaceous layer in the .01 acre plot.

The number of fruit per plant, the number of runners per plant and the growth form, whether vertical, horizontal or intermediate, was also recorded for *Pieris*.

Soil samples were taken from six locations within the study area and the thickness of litter, fermentation layer, and humus was measured at each site. The pH of each layer was measured with a Leeds and Northrup pH meter using a soil to water ratio of one to one (Jackson, 1958). The samples were prepared and analyzed for calcium, magnesium, potassium, sodium, manganese and zinc content according to the procedure described in Appendix A.

At four sites within the study area, maximum-minimum thermometers were placed at three different levels: one foot above the litter, in the litter and at six inches below the litter surface. A precipitation gauge was placed in a clear area along the ridge. Readings from these instruments were recorded from October 1966 through September 1967.

Germination experiments were conducted with seeds of *Pieris* which had been collected in September and October of 1966 from plants in the study area. The experiments were conducted under controlled temperature and photoperiod conditions in the laboratory. The day-length was set at 16 hours daylight and 8 hours darkness with the temperature varying between 74° F. and 76° F.

The seeds were placed in petri plates on moist filter paper, 100 seeds per plate. The seeds were stratified, two plates being left without stratification, and each month thereafter, two additional plates were removed from the cold room and placed under controlled temperature and lighting. The cold room was kept at 6° C.

A total of 131 fruits was examined and the number of seeds per fruit was recorded for each. Forty-five fruits were studied microscopically and the number of seeds with viable embryos was noted.

III. RESULTS

The data concerning each tree species were combined for plots adjacent to the trail and those located at various distances from the trail after the Student's "t" test at the 95 per cent level of significance (Steel and Torrie, 1960) showed no significant differences to exist between the total basal areas of these two locations. A summary of density of tree taxa by diameter classes may be found in Appendix B.

Frequency of Trees

The frequency of the species in the tree stratum is shown in Table I, including the frequencies of these same species under 1.0 inch in diameter and as seedlings.

Pinus pungens is the only tree species to exhibit a frequency of 100 per cent with *Nyssa sylvatica* and *Acer rubrum* having the next two highest frequencies of 77.5 per cent and 72.5 per cent respectively. These three species also have the highest frequencies of trees less than 1.0 inch in diameter. However, the frequency of these species as seedlings is quite different. *Acer rubrum* has the highest frequency of 62.5 per cent with *Amelanchier arborea* and *Quercus prinus* having the next highest frequencies.

Ilex montana and *Viburnum cassinoides* were found in the two plots closest to the heath bald at the upper extent of the pine-heath, and are judged atypical of pine-heath stands.

TABLE I

PER CENT FREQUENCY OF TREE SPECIES IN THE TREE STRATUM, UNDER ONE INCH DIAMETER AND AS SEEDLINGS

Taxon	Per Cent Frequency		
	Tree Stratum	Under One Inch D.B.H.	Seed-lings
Pinus pungens	100.0	42.5	17.5
Nyssa sylvatica	77.5	45.0	12.5
Acer rubrum	72.5	30.0	62.5
Quercus prinus	45.0	12.5	25.0
Oxydendrum arboreum	40.0	5.0	10.0
Robinia pseudo-acacia	32.5	*	5.0
Hamamelis virginiana	30.0	17.5	22.5
Castanea dentata	15.0	17.5	10.0
Tsuga canadensis	15.0	17.5	20.0
Magnolia fraseri	10.0	*	5.0
Sassafras albidum	10.0	7.5	15.0
Betula lenta	7.5	7.5	10.0
Amelanchier arborea	7.5	10.0	35.0
Halesia carolina var. monticola	5.0	*	*
Ilex montana	5.0	2.5	*
Picea rubra	2.5	2.5	2.5
Quercus rubra	2.5	2.5	15.0
Fagus grandifolia	2.5	*	5.0
Acer pensylvanicum	*	10.0	2.5
Quercus velutina	*	2.5	*
Clethra acuminata	*	*	7.5

*Species absent.

Density and Basal Area of Trees

The mean density and per cent total basal area of the tree species may be found in Table II. As can be seen, five species are the most prevalent. *Pinus pungens* is dominant with *Nyssa sylvatica*, *Acer rubrum*, *Quercus prinus* and *Oxydendrum arboreum* the next most numerous.

The diameters of the tree species were placed in classes to correspond with ones used by Whittaker (1956) to characterize the growth and survival of trees into the larger size classes in various moisture gradients. A logarithmic and linear graph of tree species in the Bullhead Trail pine-heath as compared to the pine-heath used by Whittaker is shown in Figure 6. As can be seen in the figure, 59.6 per cent of the stems in the stand were within the smallest size class (1.0-3.0 inches) while Whittaker found approximately 66 per cent to fall within this class. In the size class 16-18 inches, Whittaker found approximately 0.36 per cent of the stems as compared to 0.16 per cent in the study area. This large number of stems in the smaller size classes and small number in the large size classes would imply a continuous reproduction and replacement in both stands.

Whittaker states that reproduction in the pine stands in the Smokies is cyclic. This periodic reproduction of the stand is indicated in Figure 7a by the large number of stems in the small diameter classes and the large number also in the 8, 9, and 10 inch classes for *Pinus pungens*. Using these same diameter classes for *P. pungens* in the study area gives a rather continuous decrease in the number of

TABLE II

MEAN DENSITY PER PLOT AND PER CENT TOTAL BASAL AREA OF TREES IN THE STUDY AREA

Taxon	Density	Per Cent Total Basal Area
Pinus pungens	44.95	85.05
Oxydendrum arboreum	17.75	1.15
Nyssa sylvatica	12.60	5.12
Acer rubrum	3.93	2.75
Hamamelis virginiana	3.60	<1.00
Quercus prinus	2.08	3.79
Robinia pseudo-acacia	<1.00	<1.00
Castanea dentata	<1.00	<1.00
Tsuga canadensis	<1.00	<1.00
Magnolia fraseri	<1.00	<1.00
Sassafras albidum	<1.00	<1.00
Betula lenta	<1.00	<1.00
Amelanchier arborea	<1.00	<1.00
Halesia carolina var. monticolor	<1.00	<1.00
Ilex montana	<1.00	<1.00
Viburnum cassinoides	<1.00	<1.00
Picea rubra	<1.00	<1.00
Quercus rubra	<1.00	<1.00
Fagus grandifolia	<1.00	<1.00

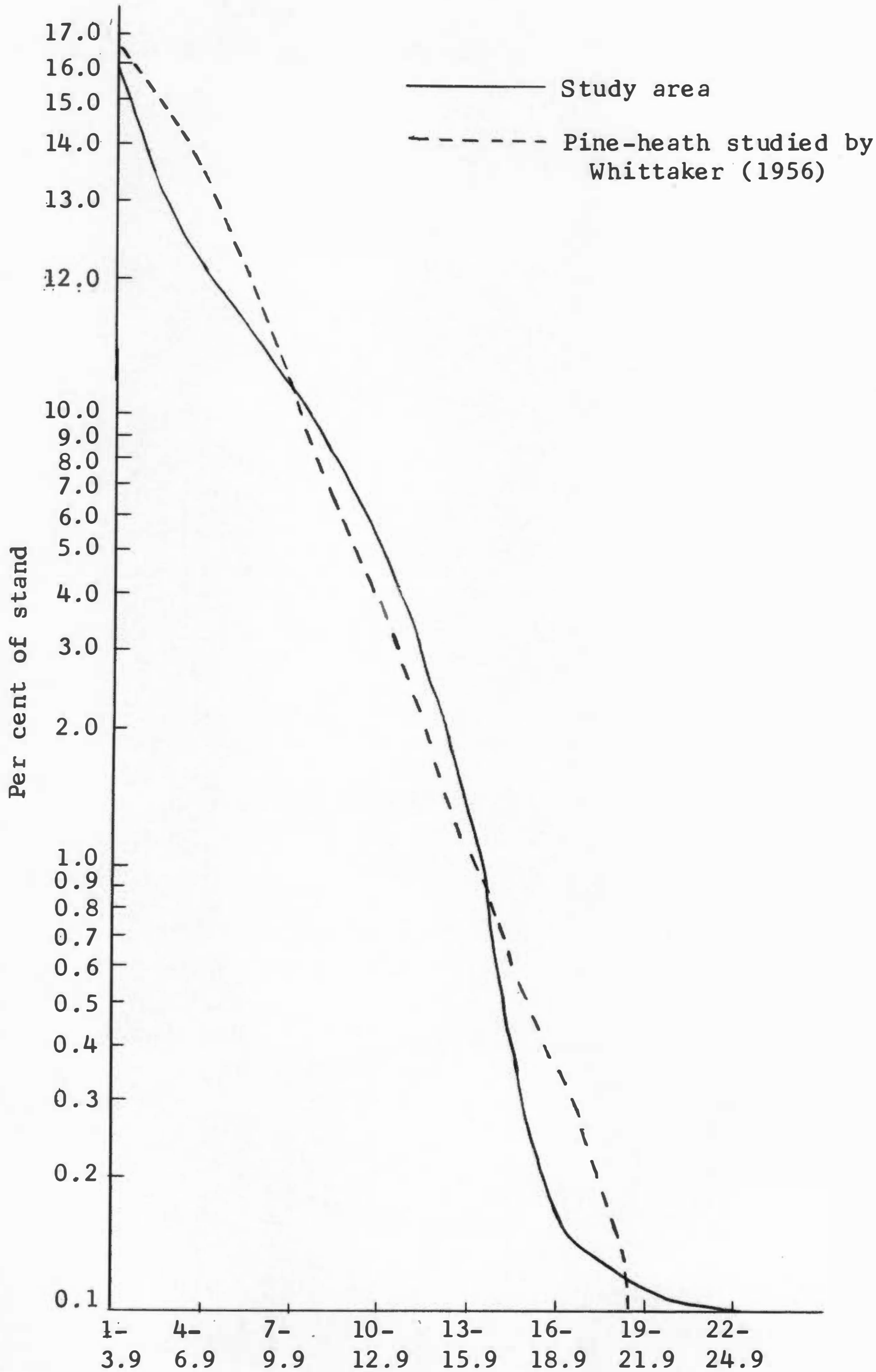


Figure 6. A comparison of diameter distribution of all stems in two pine-heath stands: the study area and a stand investigated by Whittaker (1956).

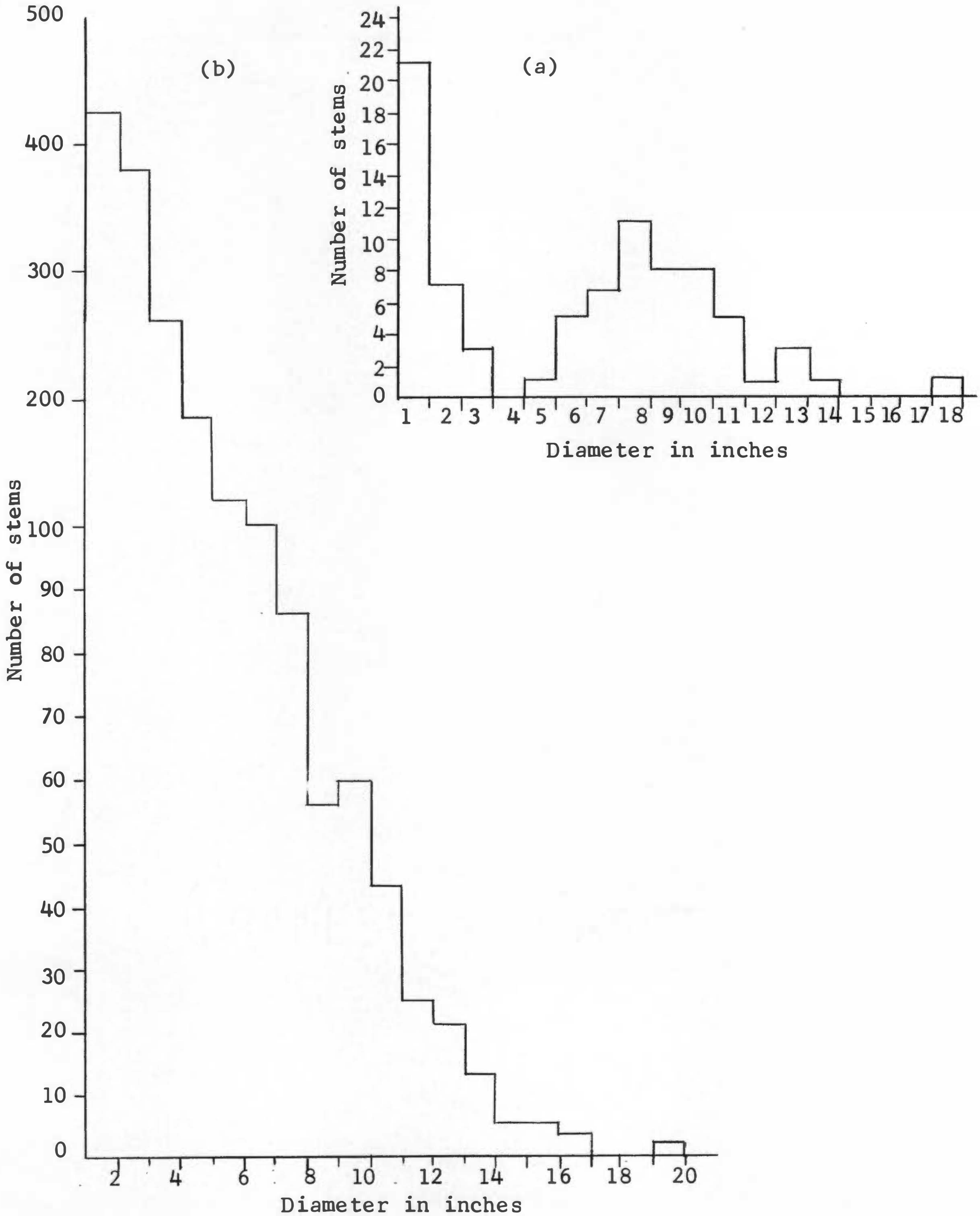


Figure 7. (a) Pinus pungens in pine-heath community studied by Whittaker (1956). (b) P. pungens in study area.

stems from the small to the large diameters as illustrated in Figure 7b. This would indicate that reproduction in this stand has been continuous.

Frequency and Density of Shrubs

The data were again combined for the shrubs since no significant differences were found between the total number of stems in the disturbed and undisturbed areas using the Student's "t" test. A summary of density of shrub taxa by diameter classes may be found in Appendix C. *Kalmia latifolia* had a 100 per cent frequency in the shrub stratum. *Rhododendrum maximum*, *Vaccinium* sp. and *Pieris floribunda* had frequencies of 75.0, 85.0, and 72.5 per cent respectively. The density of these shrubs was calculated by using the mean number of stems within plots and not the number of clumps of the species. This was thought to be a better estimate because it was difficult at times to distinguish one clump from another. *Pieris floribunda* had the highest density of 97.5 stems per plot. *Vaccinium* sp. had a density of 32.6, *Kalmia latifolia*, 86.6 and *Rhododendrum maximum*, 3.2.

Herbaceous Cover

The taxa contributing to the herbaceous cover and their frequencies are listed in Table III. Such taxa as *Aster* sp., *Gerardia flava*, *Andropogon scoparius*, *Habenaria ciliaris* and *Solidago* sp. were found to be present only along the edge of the trail. *Epigaea repens*, *Galax aphylla* and *Gaultheria procumbens* were the most prevalent taxa.

TABLE III

SPECIES PRESENT AND THEIR FREQUENCY
IN THE HERBACEOUS COVER

Taxon	Frequency
Andropogon scoparius	12.5
Aster sp.	2.5
Chimaphila maculata	5.0
Epigaea repens	95.0
Galax aphylla	92.5
Gaultheria procumbens	90.0
Gerardia flava	10.0
Habenaria ciliaris	5.0
Lycopodium obscurum	40.0
Medeola virginiana	12.5
Melampyrum lineare	40.0
Monotropa uniflora	2.5
Pteridium aquilinum	55.0
Solidago sp.	22.5
Trillium undulatum	12.5
Vaccinium sp.	45.0

The most numerous lichens in the study area were *Cetraria tuckermanii*, *Parmelia caperata*, *Pseudevernia consocians*, *Alectoria bicolor* and *Usnea comosa*.

Pieris floribunda

The Student's "t" test at the 95 per cent level of significance was used to test the significance between the measurements recorded for *Pieris floribunda* in plots adjacent to and off the trail. No significant difference was found for the total number of stems nor the number of fruits per plant between these two areas. The data therefore were combined as before. However, a highly significant difference was found between the average diameters in these two areas. The average stem diameter in plots off the trail was 0.62 inch while in plots along the trail, the average stem diameter was 0.45. The average number of runners per plant was found to be significantly different at the 80 per cent level of significance. The average number of runners was 8.13 for plots off the trail and an average number of 5.59 for plots along the trail. The standard deviation and range of each of these means may be found in Table IV.

From fruit collected along the Bullhead Trail in the fall of 1966, it was found that there is an average of 32.2 seeds per fruit, 20.9 of these having fully developed embryos. The standard deviation and range of these means may be found in Table IV also. In the field, it was determined that *Pieris* had an average of 59.4 fruit per plant. It may be concluded from this that one *Pieris* plant would probably have

TABLE IV

THE MEAN, STANDARD DEVIATION AND RANGE OF SEVERAL CHARACTERS OF *PIERIS FLORIBUNDA*

	$\bar{x}$	Standard Deviation	Range
Off trail plots			
diameter	0.62	0.62	0.1-3.0 in.
Number of runners	8.13	8.94	0-50
On trail plots			
diameter	0.45	0.40	0.1-2.0 in.
Number of runners	5.9	10.15	0-50
Number seeds/fruit	32.2	4.12	23-43
Number seeds with developed embryos	20.9	3.46	14-27

approximately 1242 seeds with fully developed embryos. From this it may be deduced that one acre of this pine-heath should produce approximately twelve million *Pieris* seeds with fully formed embryos. Yet only one seedling per acre was found in the sampling.

Germination experiments conducted in the laboratory with these seeds gave the following results: 17.5 per cent germination for those without stratification, and 20.0 per cent germination for those with one month cold treatment. During the second month of stratification, the seeds began germinating in the cold room. These were removed from the cold room and a 19.7 per cent germination was obtained.

Environmental Study

The maximum temperatures recorded at the five stations in the study area were averaged for each time period for each of the three levels (one foot, litter, and soil) to give one maximum temperature for the study area for that time interval. This was also done for the minimum temperatures and the results are shown in Figure 8 and Figure 9.

The air temperatures were the most extreme of the three as would be expected. The maximum temperature for the soil, litter and air was recorded during the same time period for all three. For the period of April 1, 1967 to April 8, 1967, 66.0° F., 86.0° F., and 90.3° F. were recorded for soil, litter and air respectively. The minimum temperature for the litter and air was registered between February 11, 1967 and April 1, 1967. The litter reached a low of 18.0° F. and the

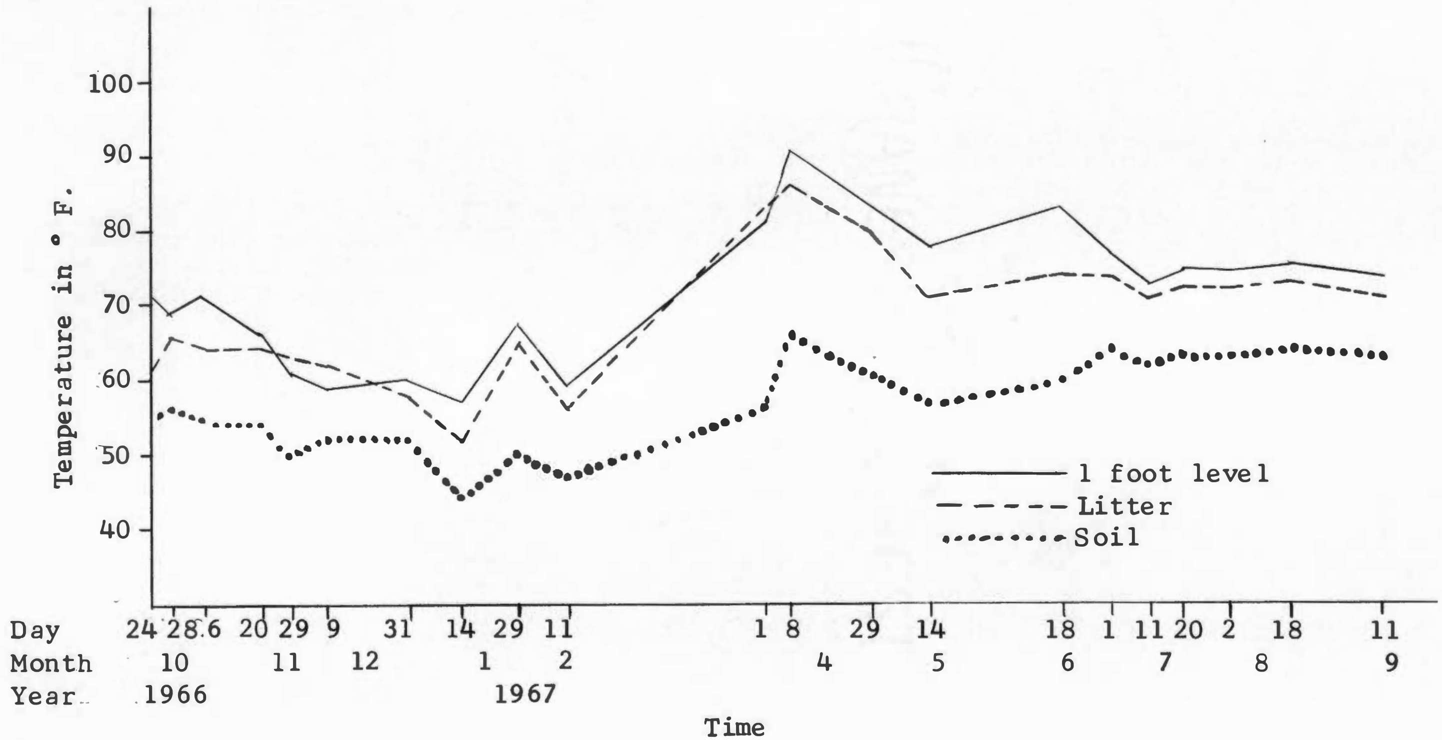


Figure 8. Average maximum temperatures for five stations in study area for the one foot level, litter, and soil.

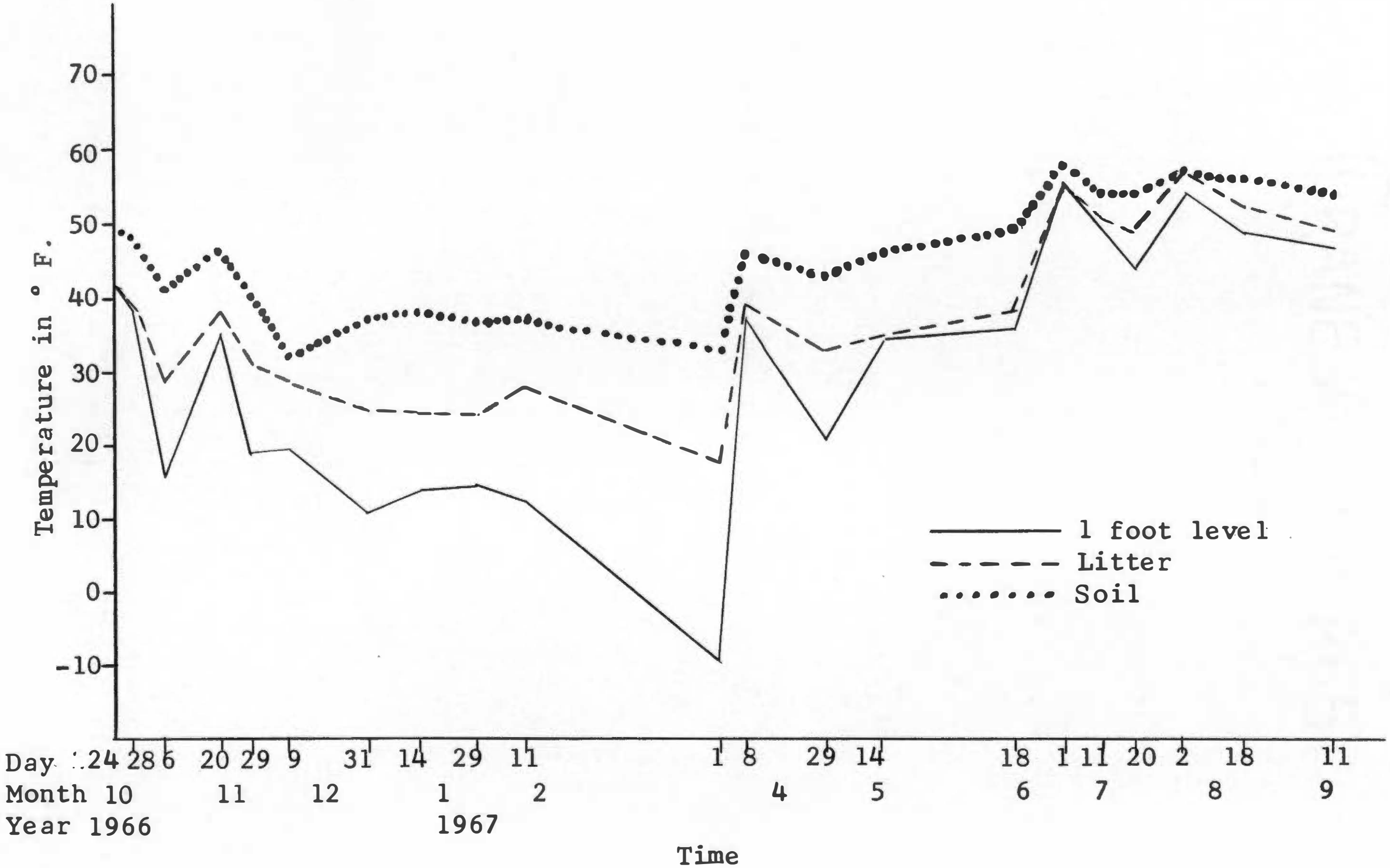


Figure 9. Average minimum temperatures for five stations in study area for the one foot level, litter, and soil.

air temperature fell to -9.4° F. The soil reached its minimum temperature of 32.0° F. during the period from November 29, 1966 to December 9, 1966.

The air temperatures for the study area which were obtained by averaging the maximum readings and the minimum readings separately from the five stations for each time period are compared to the temperatures from two other locations in the Park, Newfound Gap and Park Headquarters, in Figure 10 and Figure 11. The maximum temperature and the minimum temperature for each time period for these two locations were obtained from the daily maxima and the daily minima. Newfound Gap is at an elevation of 5046 feet while the Park Headquarters station is 1400 feet above sea level. The pine-heath temperatures generally ranged between those for the other two localities. The minimum temperatures more nearly coincided for the three areas than the maximum temperatures. It should be noted that the maximum temperature during this period from October 24, 1966 to September 11, 1967 was 90.3° F., recorded in the Bullhead pine-heath.

In Figures 12 and 13, the maximum and minimum air temperatures discussed above for the study area are compared with those of Newfound Gap and Park Headquarters. For each group of points, a least squares fit was obtained. Regression statistics appear in Table V.

It can be seen in the table and graphs that the maximum temperatures for the Bullhead pine-heath are higher than those for Newfound Gap but are lower than those for Park Headquarters. An increase of one degree at either site means an increase of slightly less than one

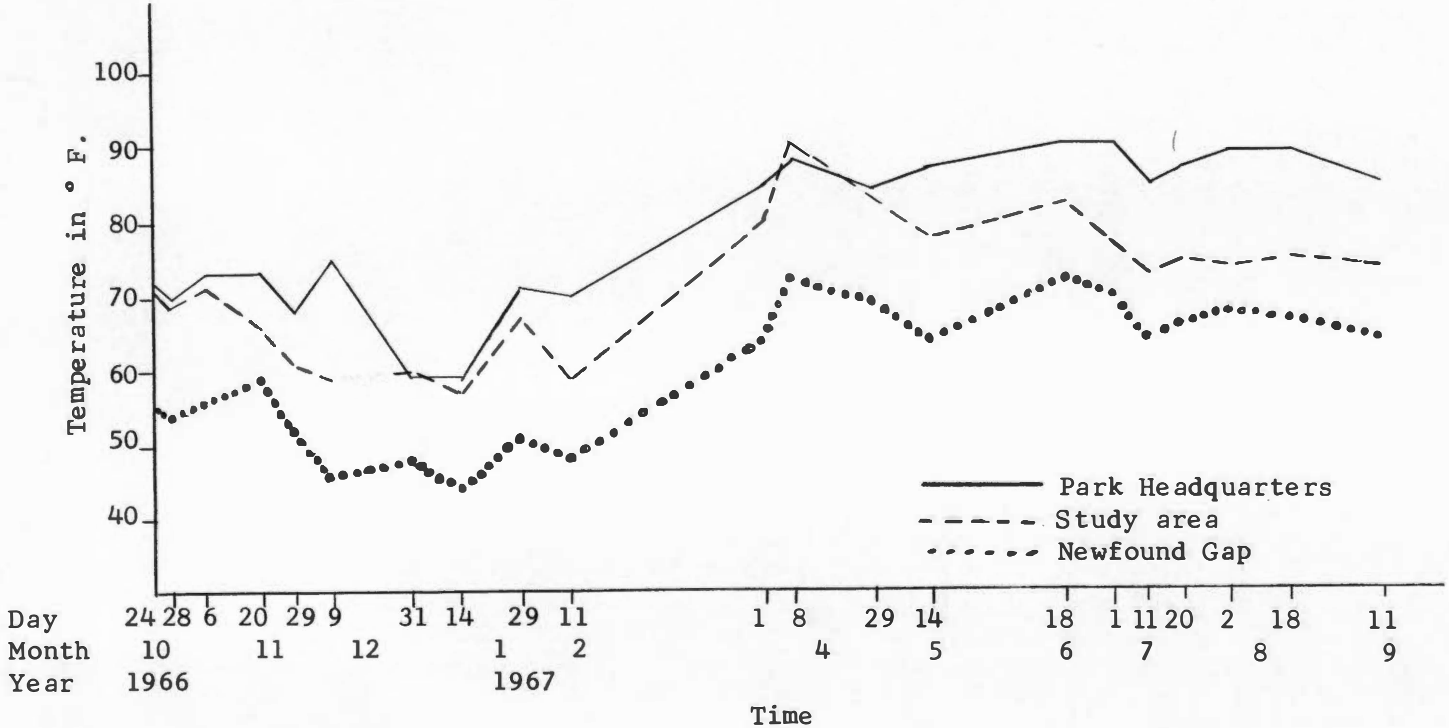


Figure 10. Comparison of average maximum temperatures for three areas in Great Smoky Mountains National Park: Park Headquarters, study area, and Newfound Gap.

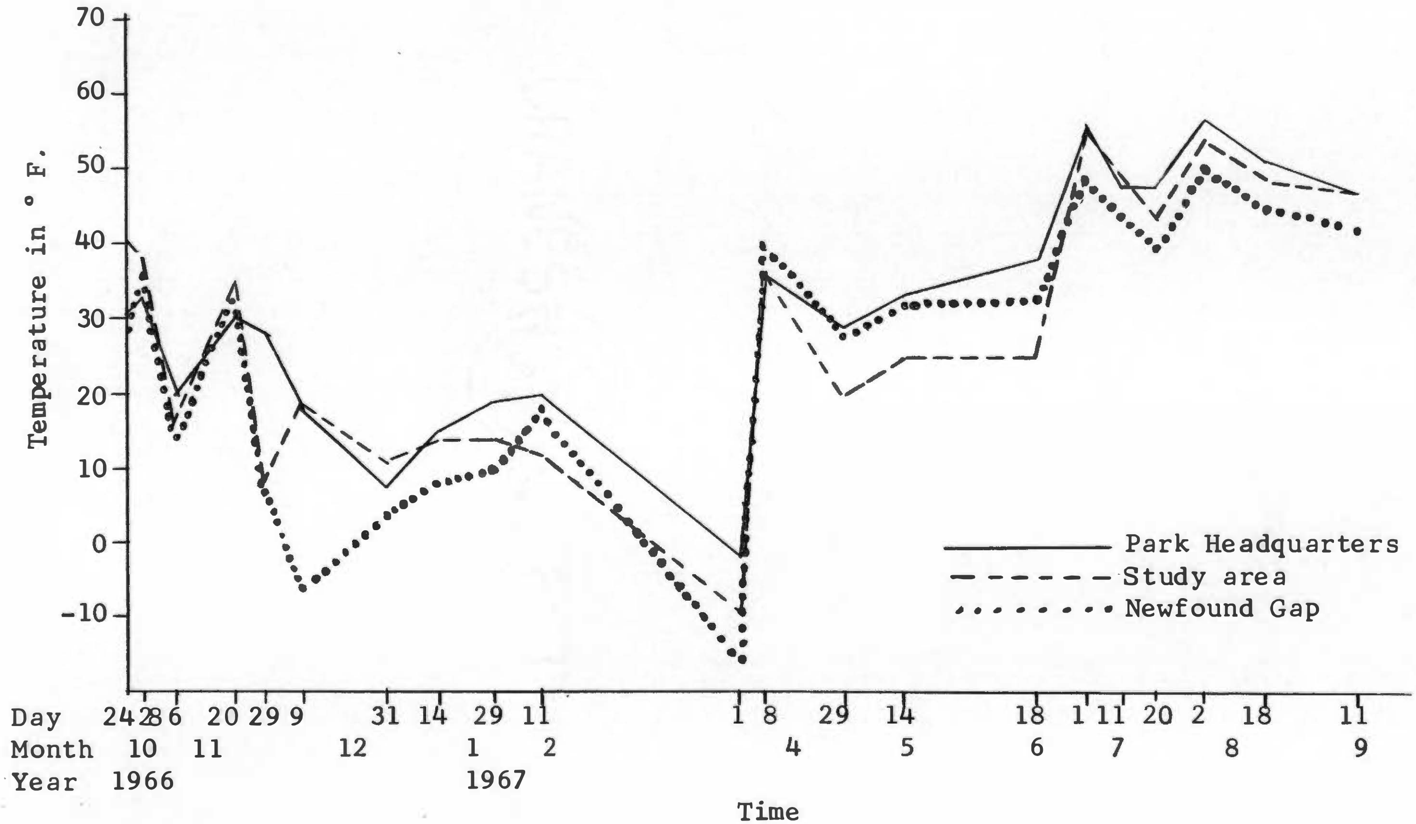


Figure 11. Comparison of average minimum temperatures for three areas in Great Smoky Mountains National Park: Park Headquarters, study area, and Newfound Gap.

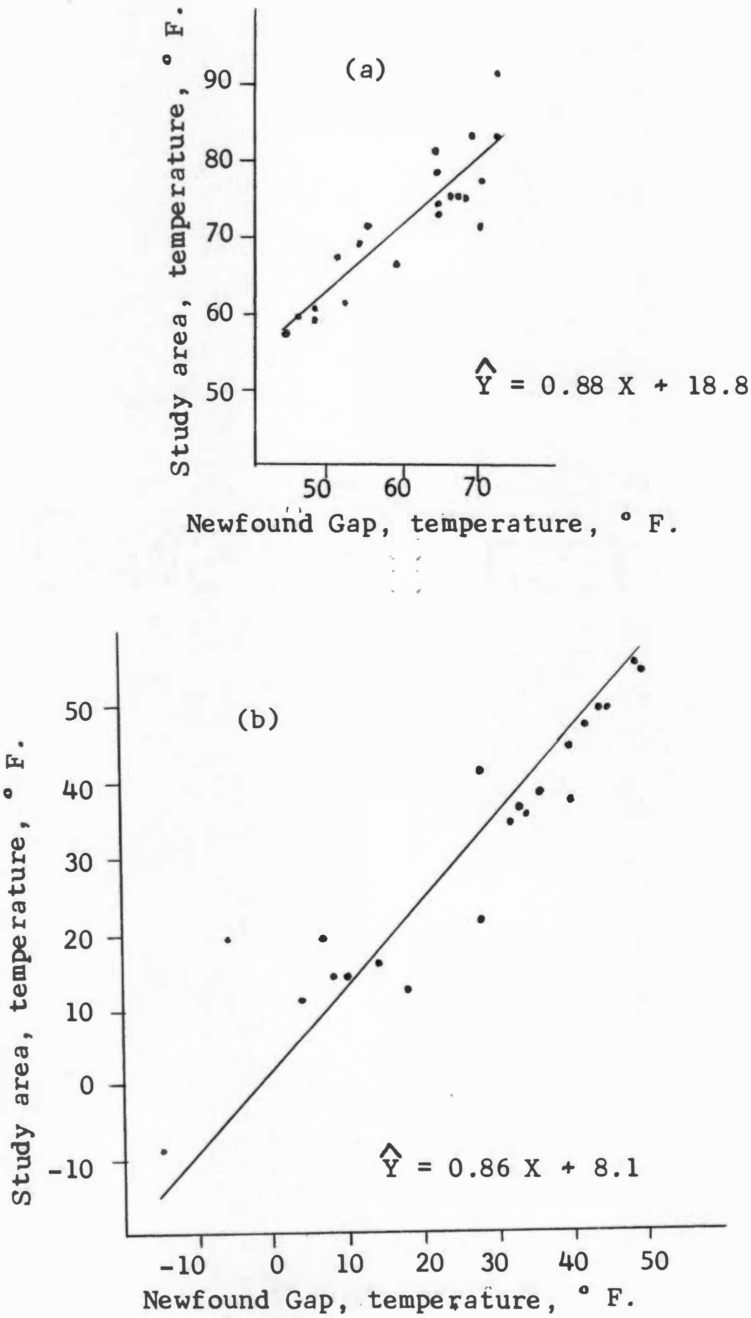


Figure 12. Relation of Newfound Gap and study area maximum (a) and minimum (b) temperatures.

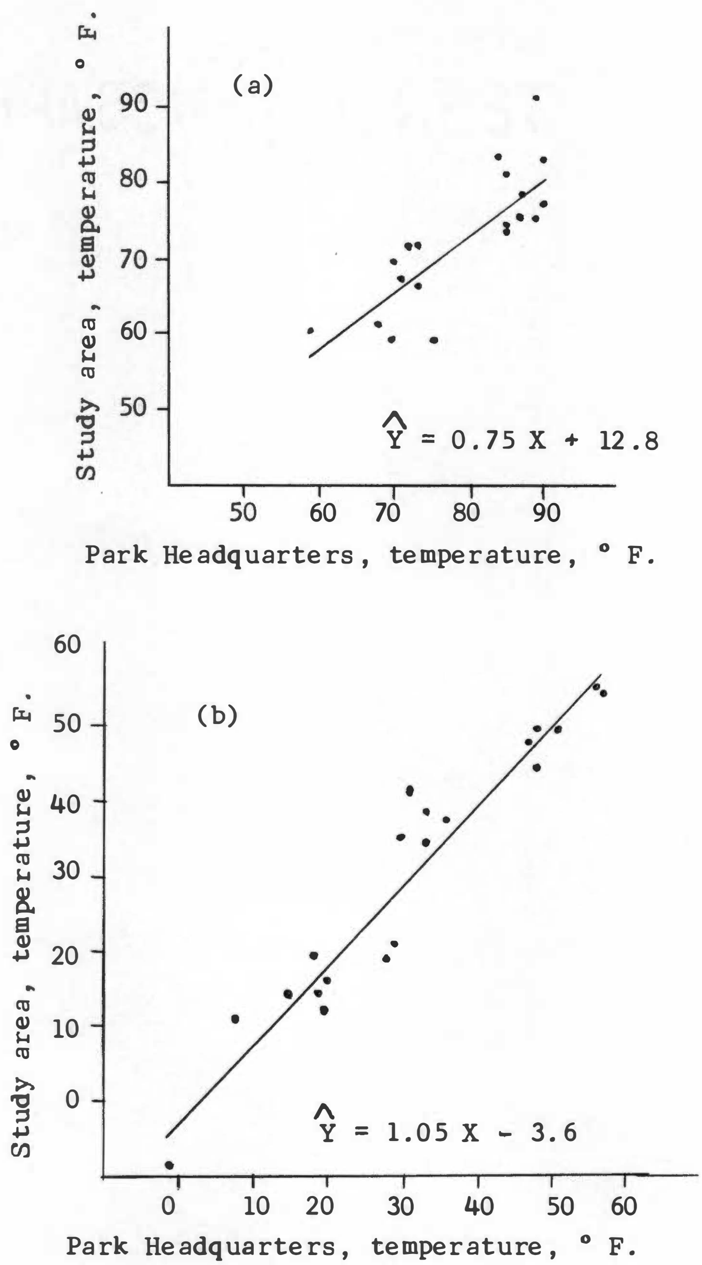


Figure 13. Relation of Park Headquarters and study area maximum (a) and minimum (b) temperatures.

TABLE V

VALUES OF COMPONENTS OF REGRESSION EQUATIONS OF TEMPERATURES

Y	X	A	b	r
Minimum				
Pine-heath	Newfound Gap	8.1	0.86	0.93
Pine-heath	Park Headquarters	-3.6	1.05	0.97
Maximum				
Pine-heath	Newfound Gap	18.8	0.88	0.90
Pine-heath	Park Headquarters	12.18	0.75	0.84

degree on the Bullhead. The minimum temperatures of the study area are lower than those of Park Headquarters and have practically a one to one slope. The minima for the pine-heath are higher than those for the Newfound Gap station, and change at slightly less than a one to one rate.

The cumulative rainfall for these same three locations is shown in Figure 14 for November 6, 1966 through September 11, 1967. Newfound Gap, with over 80 inches of rainfall for this eleven month period, had not quite twice the amount of precipitation as the pine-heath on Mt. LeConte. Park Headquarters had slightly over 50 inches, still above the 47 inches received in the gauge in the pine-heath.

Of the soil samples taken from the study area, samples one and two are from sites close to the point of transition from pine-heath to heath bald; samples three and four are from the pine-heath; samples five and six are from the lower edge of the pine-heath near the trail, sample six being closest to the oak forest.

McGinnis (1958) described a soil profile for a table mountain pine stand in Cades Cove in the Great Smoky Mountains National Park at an elevation of 2800 feet with a shrub cover composed of ericaceous plants. A comparison of McGinnis' profile with those from the Bullhead Trail pine-heath appears in Table VI.

The results of the analysis of the soil samples taken from the study area are shown in Table VII. Chemical analysis was not conducted on the A_{OO} horizon.

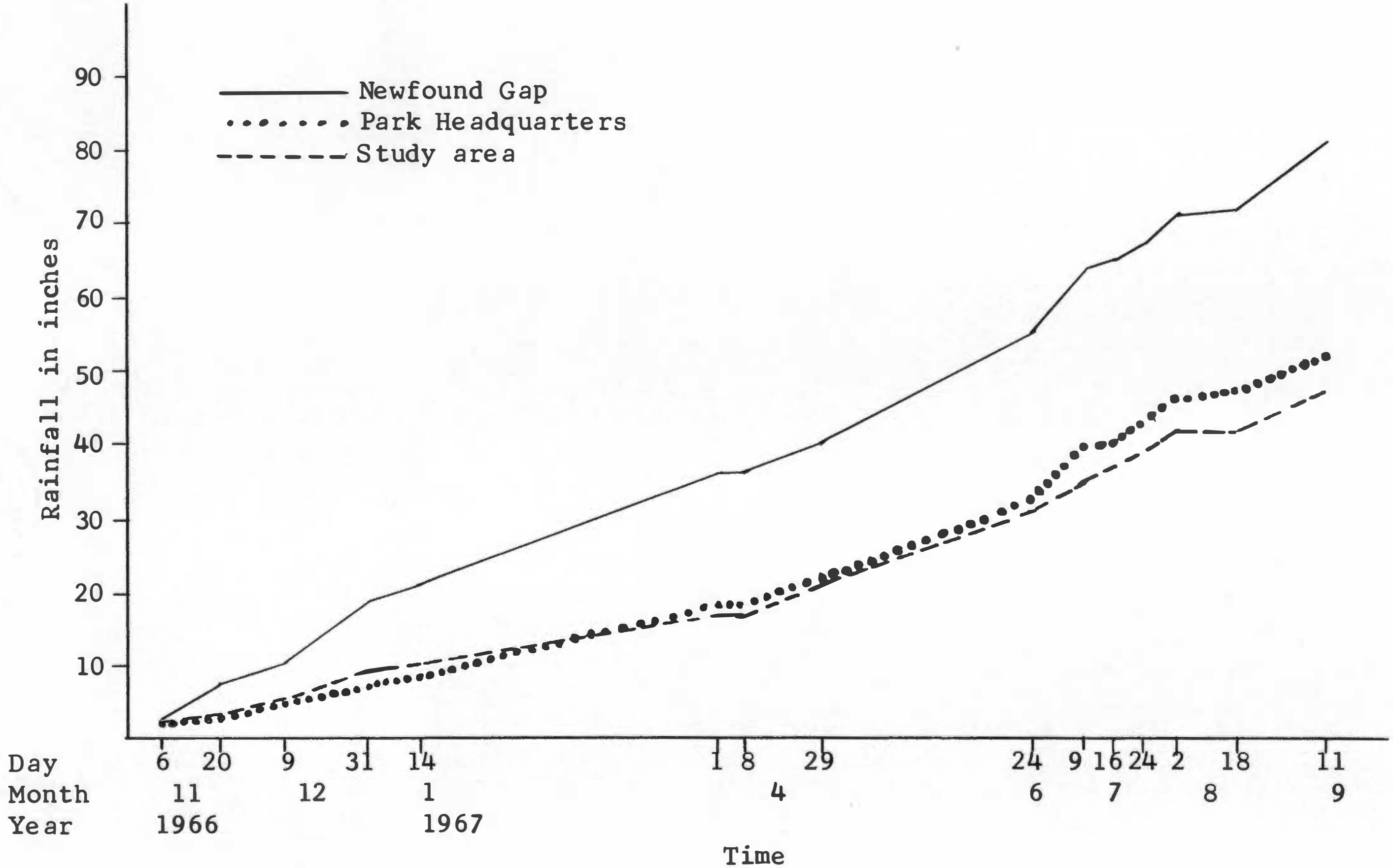


Figure 14. A comparison of the cumulative rainfall for three locations in Great Smoky Mountains National Park: Newfound Gap, study area, and Park Headquarters.

TABLE VI

SOIL PROFILES AND pH VALUES FROM THE BULLHEAD TRAIL PINE-HEATH AND A PINE-HEATH AT 2800 FEET ELEVATION STUDIED BY McGINNIS

Horizon	Thickness in cm. Study Area		McGinnis	pH Study Area
A_{oo}	Sample 1	2.5	1.1	4.5
	2	0.6		4.7
	3	0.5		4.9
	4	0.5		4.8
	5	0.5		4.5
	6	0.5		4.7
F	Sample 1	6.3	0.5	3.7
	2	6.3		3.4
	3	12.6		3.7
	4	6.3		3.8
	5	7.6		3.8
	6	6.3		3.5
H	Sample 1	[a]	1.2	[a]
	2	23.4		3.1
	3	5.1		3.7
	4	0.6		4.2
	5	0.3		4.5
	6	12.6		3.3
A_1	Sample 1	[b]		4.4
	2			[a]
	3			4.6
	4			4.8
	5			4.8
	6			4.7

[a]Horizon not present in sample.

[b]Not measured.

TABLE VII

AVAILABLE CATIONS OF SOILS IN THE STUDY AREA

Horizon		K[a]	Na[a]	Ca[a]	Mg[a]	Mn[b]	Zn[b]
F	Sample 1	0.87	0.00	5.27	1.78	0.02	1.48
	2	4.79	4.82	1.67	5.72	0.00	5.15
	3	0.00	2.90	5.55	1.29	0.00	4.58
	4	0.87	4.17	2.22	0.36	0.07	2.70
	5	1.31	0.30	3.61	2.85	0.00	4.38
	6	0.44	7.41	16.10	0.36	0.01	3.35
H	Sample 1	c					
	2	0.00	11.28	1.39	1.43	0.00	2.25
	3	4.37	2.57	1.39	0.72	0.00	$<$0.01
	4	1.74	2.26	1.39	1.29	0.05	0.10
	5	3.05	1.61	1.39	1.29	0.00	$<$0.01
	6	0.00	3.87	22.77	0.00	0.00	0.20
A_1	Sample 1	5.68	13.54	3.33	0.72	0.00	$<$0.01
	2	c					
	3	0.44	1.29	1.39	0.00	0.00	$<$0.01
	4	0.00	0.97	2.50	d	0.02	$<$0.01
	5	0.44	1.61	1.39	1.29	0.00	$<$0.01
	6	4.78	3.55	18.05	0.72	0.00	$<$0.01

[a]Expressed in meq./100 g.

[b]Expressed in p.p.m.

[c]Horizon not present in sample.

[d]Lost during analysis.

The pH of the F horizon ranged from 3.4 to 3.8. In general, the acidity increased from the A_{oo} to the F horizon and began to decrease from the H to the A_1. The thickness of the humus was the greatest (23.4 cm.) for the sample taken adjacent to the heath bald.

Little work has been done on the chemical analysis of soils of pine-heath stands. McGinnis found a concentration of 0.98 and 3.80 meq. for potassium and calcium, respectively, in the H horizon. The pH was 3.8, not too different from that found in the study area. For the A_1, he found potassium to have a concentration of 0.45 meq. and calcium, 0.70 meq. The pH was 4.1, lower than the pH for the A_1 in any of the samples from the Bullhead Trail pine-heath.

IV. DISCUSSION AND CONCLUSIONS

It is to be expected that a pine-heath would occupy the south and southwest facing slopes of the mountains of the Smokies. These areas are both the most xeric and the most extreme with respect to temperature in comparison to other areas at comparable elevations.

The soil temperatures show less seasonal variation than the temperatures of the air and litter. This is to be expected because the soil functions as an insulator, retaining heat longer and consequently staying at a more constant temperature throughout the year.

The temperatures of the litter (Figure 8, page 30, and Figure 9, page 31) are more closely aligned to those of the air than the soil, but still not as extreme as those of the air. The temperature of the litter was considered important because it is here that the seeds of *Pieris* over winter and the scarcity of seedlings was quite obvious. The only location where *Pieris* was found to have seedlings was adjacent to the trail and then only in a very small number. Any extreme temperatures in this area could possibly influence the number of seedlings present. Freezing temperatures immediately after germination of the seedling could kill the new seedling. Since no dormancy period was observed in the germination of the seeds, it is possible that these seeds might germinate during warm periods in the winter and subsequently be killed by the return of freezing temperatures. It should be noted here that seeds which were stratified for two months in the laboratory began germinating while still under these conditions. However, the resulting seedlings were not subjected to freezing temperatures so the exact effects cannot be stated with certainty.

Another critical factor in Pieris seed germination is the amount of rainfall received during the winter in these pine-heath communities. Pine-heaths are notably xeric habitats, and the amount of rainfall received for the winter months falls below that received at the Park Headquarters weather station. The seeds used in the germination experiments in the laboratory were kept moist for the duration of their stratification so again it cannot be shown with evidence that desiccation would injure the seeds, but it seems a good possibility of being a contributing factor.

The soils in which Pieris was growing were diverse with respect to the thickness of the first three horizons. In comparison to the soil profile of the pine-heath reported by McGinnis (1958), the horizons in the study area are considerably deeper. The pine-heath which McGinnis investigated was at an elevation of 2800 feet, suggesting warmer temperatures than those of the Bullhead Trail pine-heath. With these lower temperatures on the Bullhead, the accumulation of litter and undecomposed material should increase because of a lower rate and shorter season of decomposition. The humus and A_1 were not as a whole more acidic than those of the other pine-heath. The greater acidity of soils is thought to slow the rate of decomposition.

The pine-heath on the Bullhead Trail is very similar to the heath bald described by McCracken et al. (1962) with respect to its low fertility of calcium and potassium. Manganese was almost entirely absent from the samples. A high concentration of zinc occurs in the F layer and decreases gradually until it almost disappears in the A_1 horizon, but the amount in the F horizon is still lower than the amount normally found in soils (Swaine, 1955).

According to Whittaker, this pine-heath stand should be maintaining itself when compared to the pine-heath he studied shown in Figure 6, page 23. Approximately 59 per cent of the total number of stems in the stand fell within the 1-3 inch diameter class as compared to approximately 66 per cent for the stand studied by Whittaker.

There are in actuality two tree layers in the Bullhead Trail pine-heath, the higher composed of the mature pines and the lower layer of deciduous trees. The frequency of the deciduous trees in the tree stratum, four species having over 40 per cent frequency (Nyssa sylvatica, Acer rubrum, Quercus prinus and Oxydendrum arboreum) may indicate the invasion of the pine-heath by the forests of lower elevations. The frequency of pine seedlings and those under one inch in diameter is quite noticeably smaller than the 100 per cent frequency observed for the mature trees. The deciduous species have a high frequency as seedlings relative to pine but their frequency decreases as they reach sapling size. This is a reversal of what one would expect in a stand which is maintaining itself. One would expect a greater frequency of the dominant species as seedlings than the others, these being pine and the deciduous species respectively. The pine-heath is relatively open except for the shrub stratum which is quite dense and continuous throughout. The denseness of these shrubs could be a major factor in the maintenance of the pine-heath by diminishing the amount of light which reaches the ground. The light intensity is so low that it could keep pine seedlings from becoming established. If this were true, the number of pines would slowly decrease and the pine-heath would eventually become a heath bald. However, there is a high frequency of deciduous seedlings in the area. As more and more deciduous trees become established, their shade would cause the number of heath shrubs beneath them to diminish and it would eventually become a part of the oak forest of lower elevations.

Whittaker (1956) considers the pine-heath a topographic climax and uses as evidence the bimodal size-class frequency curve shown in Figure 7, page 24. The same frequency curve for the Bullhead Trail pine-heath does not give a bimodal frequency curve. While Cain (1937) thought that fires in these pine-heaths help perpetuate the dominance of pine, the figure mentioned above indicates that this pine-heath has had a rather uninterrupted growth and reproduction for a considerable period. Since this stand has remained undisturbed for what appears to be a long time, one would expect it to be invaded by both the heath bald and oak forest species. It seems much more likely at the present that this particular pine-heath may eventually become a heath bald because of the dense ericaceous shrub layer already present and the low survival rate of deciduous seedlings.

With a low germination rate in the laboratory and the almost complete absence of seedlings in the pine-heath, a frequency of 72.5

per cent and a density of 97.5 for Pieris were not to be expected. However, with an average of five to eight runners per plant, Pieris is able to keep its high degree of coverage in this area. It reproduces vegetatively by runners and by layering.

A significant difference was found between the diameters and number of runners of Pieris from the two locations of plots, but not between any other characteristics of Pieris investigated. The difference in diameters and number of runners could easily be a function of the age of the plant, those off the trail having been established before the trail was cut about thirty years ago.

More experiments with the seeds of Pieris are necessary to be able to show the effects of environmental extremes as are encountered in an area such as this pine-heath. A comparison of such factors as soils and temperature extremes of the Bullhead Trail pine-heath and another location of Pieris as the ones in North Carolina along the Blue Ridge Parkway would more than likely give the answer to many questions still unanswered about Pieris. Although no conclusive evidence has been presented here, it is still thought that the creation of a disturbance area is one of the major factors in the establishment of Pieris. After establishment, Pieris may continue to maintain itself and even increase its coverage by vegetative reproduction.

V. SUMMARY

The role of Pieris floribunda Benth. and Hook. in a pine-heath community in the Great Smoky Mountains National Park was studied. The pine-heath was located on the Bullhead of Mt. LeConte at an elevation of approximately 4100 feet.

Forty .05 acre plots were established for sampling stand characteristics and to test for differences between Pieris and its surroundings along the trail and Pieris growing in dense shrub cover off the trail.

The diameters and number of stems were recorded for both trees and shrubs in addition to a species list of the herbaceous cover. Special notes were made for Pieris with respect to number of runners and number of fruits per plant.

Germination experiments were conducted with seeds of Pieris collected in the study area the previous fall. Pieris was found to have 20.0 per cent germination under laboratory conditions.

The pine-heath along the Bullhead Trail is a typical one with respect to environment and vegetational composition. Its seasonal maximum and minimum temperatures are more extreme than the lower elevations yet not as extreme as the higher elevations in the Park. By use of the derived regression equations, the maximum or minimum temperatures of the pine-heath may be predicted from either the maximum or minimum temperatures at Park Headquarters or Newfound Gap. The amount of rainfall received in the pine-heath is lower than that of both Newfound Gap and Park Headquarters.

It is thought that this particular pine-heath is being invaded by the heath bald located at its upper limit and will eventually become a heath bald if fire does not perpetuate the pine-heath.

No significant difference was found between the two locations of plots with respect to the density of *Pieris*, and therefore it cannot be concluded that *Pieris* requires a disturbance or break in the canopy to become established. However, it is still thought that further study may prove this to be true.

LITERATURE CITED

LITERATURE CITED

Association of Agricultural Chemists. 1945 (Ed. 6). Official and tentative methods of analysis of the Association of Official Agricultural Chemists. Washington, D. C.

Bailey, L. H. 1930. The standard cyclopedia of horticulture. The Macmillan Co., New York. 3 vols.

Cain, S. A. 1930. Certain floristic affinities of the trees and shrubs of the Great Smoky Mountains and vicinity. Butler Univ. Bot. Stud. 1:129-150.

________. 1931a. An ecological study of the heath balds of the Great Smoky Mountains. Butler Univ. Bot. Stud. 1:177-208.

________. 1931b. Ecological studies of the vegetation of the Great Smoky Mountains of North Carolina and Tennessee. I. Soil reaction and plant distribution. Bot. Gaz. 91:22-41.

________. 1937. A preliminary guide to the Greenbrier-Brushy Mountain Nature Trail, the Great Smoky Mountains National Park. Botany Dept., Univ. Tenn. (mimeographed).

Cooper, A. W. 1963. A survey of the vegetation of the Toxaway River Gorge with some remarks about early botanical explorations and an annotated list of the vascular plants of the gorge area. J. Elisha Mitchell Sci. Soc. 79(1):1-22.

Davis, J. H. 1930. Vegetation of the Black Mountains of North Carolina: an ecological study. J. Elisha Mitchell Sci. Soc. 45:291-318.

Fernald, M. L. 1950. Gray's Manual of Botany. 8th ed. Amer. Book Co., New York. 1632 + lxiv pp.

Hadley, J. B., and R. Goldsmith. 1963. Geology of the Eastern Great Smoky Mountains of North Carolina and Tennessee. Geological Survey Professional Paper 349-B. U. S. Gov't. Printing Office, Washington, D. C.

Jackson, M. L. 1958. Soil chemical analysis. Prentice-Hall, Inc., N. J. 498 + xiv pp.

Lems, K. 1962. Adaptive radiation in the Ericaceae. I. Shoot development in the Andromedeae. Ecology 43:524-528.

Li, Hui-Lin. 1952. Floristic relationships between eastern Asia and eastern North America. Trans. Amer. Phil. Soc. 42:371-429.

McCracken, R. J., R. E. Shanks, and E. E. C. Clebsch. 1962. Soil morphology and genesis at higher elevations of the Great Smoky Mountains. Soil Sci. Soc. Am. Proc. 26:384-388.

McGinnis, J. T. 1958. Forest litter and humus types of East Tennessee. Master's thesis. The University of Tennessee, Knoxville.

Palser, Barbara F. 1951. Studies of floral morphology in the Ericales. I. Organography and vascular anatomy in the Andromedeae. Bot. Gaz. 112:447-485.

_______. 1952. Studies of floral morphology in the Ericales. II. Megasporogenesis and megagametophyte development in the Andromedeae. Bot. Gaz. 114:33-52.

Racine, C. H. 1966. Pine communities and their site characteristics in the Blue Ridge Escarpment. J. Elisha Mitchell Sci. Soc. 82(2):172-181.

Ramseur, G. S. 1960. The vascular flora of high mountain communities of the Southern Appalachians. J. Elisha Mitchell Sci. Soc. 76:82-112.

Rodgers, C. L. 1965. The vegetation of Horsepasture Gorge. J. Elisha Mitchell Sci. Soc. 81:103-112.

Shanks, R. E. 1954. Climates of the Great Smoky Mountains. Ecology 35:354-361.

Steel, R. G., and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., New York. 481 + xvi pp.

Swaine, D. J. 1955. The trace-element content of soils. Commonwealth Agricultural Bureaux, England. 157 + viii pp.

Tanner, J. T. 1963. Mountain temperatures in the Southeastern and Southwestern United States during late spring and early summer. J. of Applied Meteorology 2(4):473-483.

Thornthwaite, C. W. 1948. The climates of North America according to a new classification. Geogr. Rev. 21(4):633-655.

Whittaker, R. H. 1956. Vegetation of the Great Smoky Mountains. Ecol. Monog. 26:1-80.

———. 1966. Forest dimensions and production in the Great Smoky Mountains. Ecology 47(1):103-121.

Williams, R. H., and H. J. Oosting. 1944. The vegetation of Pilot Mountain, North Carolina: A community analysis. Bull. Torrey Bot. Club 71:23-45.

Wood, C. E. 1961. The genera of Ericaceae in the Southeastern United States. J. Arnold Arboretum 42:10-80.

APPENDIXES

APPENDIX A

PROCEDURE FOR THE PREPARATION OF SOIL SAMPLES

All samples were air dried and passed through a 2 mm. sieve. Ten gram samples were weighed and placed in 250 ml. glass stoppered flasks. Fifty ml. of normal ammonium acetate adjusted to pH 7.0, by adding acetic acid or ammonium hydroxide as necessary, was added and the flask was shaken in a mechanical shaker for one half hour. The flasks and contents were allowed to stand overnight. Certain samples (i.e., litter) required more than 50 ml. of acetate to wet them sufficiently. In such cases, 100 ml. of acetate was used and washing was done with 100 ml. of acetate divided into three portions.

Filtering of the leachings was carried out through a Whatman No. 42 filter under vacuum. The residue in the flasks was washed with 50 ml. of ammonium acetate divided into three portions. Each portion was used to wash the residue on the filter taking care to let each portion pass through the filter before adding another.

The filtrates were transferred to evaporating dishes and evaporated on a steam bath as nearly dry as possible (samples with considerable organic matter resisted going to dryness on the steam bath).

Three ml. of normal HNO_3 and 5 ml. H_2O_2 were added to the residues and digested on the steam bath until dry. This was repeated until a clear colorless solution resulted. (Traces of iron lent a slightly yellow color to some samples.)

The residues were dissolved in a little double distilled water and transferred to 250 ml. volumetric flasks. Double distilled water was used to make up to volume.

Cations were analyzed in suitable aliquots according to procedures outlined in the sixth edition of the A. O. A. C. under the section on analysis of plants. Blanks were run for each cation and corrections made if necessary.

APPENDIX B

SUMMARY OF TREE TAXA IN DIAMETER CLASSES BY PLOT

Plot No.	Taxa	Diameter Classes 1-3.5	3.6-7.5	7.6-10.5	10.6-13.5	13.6-16.5	16.6-19.5	19.6-22.6
1	*Acer rubrum*	3						
	Amelanchier arborea	1						
	Betula lenta	2						
	Ilex montana	7						
	Nyssa sylvatica	56	7					
	Oxydendrum arboreum	1						
	Picea rubra	1						
	Pinus pungens	1	4		1			
	Viburnum cassinoides	5						
2	*Acer rubrum*	2	4					
	Amelanchier arborea	2						
	Betula lenta	1	1					
	Ilex montana	1						
	Nyssa sylvatica	32	9					
	Oxydendrum arboreum		1					
	Pinus pungens	1	4	7	8			
	Robinia pseudo-acacia	2	3					
	Viburnum cassinoides	5						
3	*Acer rubrum*	4	3					
	Nyssa sylvatica	6	4					
	Oxydendrum arboreum	13	3	2				
	Pinus pungens	7	6	2	1			
	Robinia pseudo-acacia	1	1					

Plot No.	Taxa	Diameter Classes 1-3.5	3.6-7.5	7.6-10.5	10.6-13.5	13.6-16.5	16.6-19.5	19.6-22.6
4	*Nyssa sylvatica*	9			1			
	Oxydendrum arboreum	2						
	Pinus pungens	13	3	5	2	1		
5	*Acer rubrum*	2						
	Amelanchier arborea	1						
	Nyssa sylvatica	11						
	Oxydendrum arboreum	8						
	Pinus pungens	9	16	12		1		
	Tsuga canadensis	1	1					
6	*Acer rubrum*	8						
	Nyssa sylvatica	29						
	Pinus pungens	18	12	11	3	1		
7	*Nyssa sylvatica*	10						
	Oxydendrum arboreum	1						
	Pinus pungens	17	12	2	2	2		
	Tsuga canadensis	1						
8	*Nyssa sylvatica*	1						
	Pinus pungens	9	23	6				
9	*Nyssa sylvatica*	2						
	Pinus pungens	8	11	6	3			
	Tsuga canadensis	1						
10	*Nyssa sylvatica*	2						
	Pinus pungens	12	16	7	5	1		
11	*Acer rubrum*	3						
	Pinus pungens	1	11	9	1			

Plot No.	Taxa	Diameter Classes 1-3.5	3.6-7.5	7.6-10.5	10.6-13.5	13.6-16.5	16.6-19.5	19.6-22.6
12	*Pinus pungens*	83	13	3				
13	*Pinus pungens*	66	18	4				
14	*Acer rubrum*	1						
	Nyssa sylvatica	5						
	Pinus pungens	28	4	5	3			
	Quercus prinus	1						
	Robinia pseudo-acacia	1						
15	*Nyssa sylvatica*	4						
	Pinus pungens	94	37	2				
	Quercus prinus	1	1					
16	*Acer rubrum*	6						
	Nyssa sylvatica	7						
	Pinus pungens	41	16	2				
	Quercus prinus	8	1					
	Robinia pseudo-acacia	1						
17	*Acer rubrum*	8	2					
	Betula lenta	1						
	Hamamelis virginiana	5						
	Magnolia fraseri	1						
	Nyssa sylvatica	32	1					
	Pinus pungens		2		1			
	Quercus prinus	1	3	2				
	Robinia pseudo-acacia		1					
18	*Acer rubrum*	3						
	Nyssa sylvatica	2						
	Pinus pungens	6	22	8	1			

Plot No.	Taxa	Diameter Classes 1-3.5	3.6-7.5	7.6-10.5	10.6-13.5	13.6-16.5	16.6-19.5	19.6-22.6
19	<u>Acer rubrum</u>	1						
	<u>Nyssa sylvatica</u>	1						
	<u>Quercus prinus</u>	2						
	<u>Pinus pungens</u>	39	9	5	4			
20	<u>Acer rubrum</u>	9	1					
	<u>Hamamelis virginiana</u>	10						
	<u>Nyssa sylvatica</u>	11	1					
	<u>Pinus pungens</u>				1	1		
	<u>Quercus prinus</u>	4	3	2	2			
	<u>Robinia pseudo-acacia</u>	3	2					
21	<u>Acer rubrum</u>	2						
	<u>Oxydendrum arboreum</u>	4						
	<u>Quercus prinus</u>	3						
	<u>Pinus pungens</u>	5	23	11	4			
22	<u>Nyssa sylvatica</u>	3						
	<u>Pinus pungens</u>	49	45	5				
	<u>Robinia pseudo-acacia</u>	2						
23	<u>Sassafras albidum</u>	1						
	<u>Pinus pungens</u>	50	9	7				
24	<u>Pinus pungens</u>		16	16				
25	<u>Acer rubrum</u>	6						
	<u>Castanea dentata</u>	1						
	<u>Hamamelis virginiana</u>	18						
	<u>Nyssa sylvatica</u>	13						
	<u>Oxydendrum arboreum</u>		1					
	<u>Pinus pungens</u>	34	17	6		1		
	<u>Quercus prinus</u>		3					
	<u>Robinia pseudo-acacia</u>	1						

Plot No.	Taxa	Diameter Classes 1-3.5	3.6-7.5	7.6-10.5	10.6-13.5	13.6-16.5	16.6-19.5	19.6-22.6
26	<u>Acer rubrum</u>	2						
	<u>Castanea dentata</u>	1						
	<u>Nyssa sylvatica</u>	2						
	<u>Pinus pungens</u>	38	6	7	2			
27	<u>Acer rubrum</u>	8	1					
	<u>Castanea dentata</u>	1						
	<u>Hamamelis virginiana</u>	15						
	<u>Nyssa sylvatica</u>	28						
	<u>Oxydendrum arboreum</u>	2	3					
	<u>Pinus pungens</u>		1	2	4			1
	<u>Quercus prinus</u>	2	1	2				
	<u>Robinia pseudo-acacia</u>	1						
28	<u>Acer rubrum</u>	2						
	<u>Nyssa sylvatica</u>	7						
	<u>Oxydendrum arboreum</u>		1					
	<u>Pinus pungens</u>	1	4	3	1		1	
29	<u>Acer rubrum</u>	16	3					
	<u>Halesia carolina</u>		1					
	<u>Hamamelis virginiana</u>	11						
	<u>Nyssa sylvatica</u>	31	2					
	<u>Pinus pungens</u>	4	2	4	3	1		
	<u>Quercus prinus</u>	5	2	1				
	<u>Sassafras albidum</u>	3	1					
30	<u>Acer rubrum</u>	9	5	1				
	<u>Hamamelis virginiana</u>	21						
	<u>Nyssa sylvatica</u>	21	3					
	<u>Oxydendrum arboreum</u>	12	6					
	<u>Pinus pungens</u>			3	3			
	<u>Quercus prinus</u>	2	4					

Plot No.	Taxa	Diameter Classes 1-3.5	3.6-7.5	7.5-10.5	10.6-13.5	13.6-16.5	16.6-19.5	19.6-22.6
	Q. rubra		2					
	Sassafras albidum		2					
	Tsuga canadensis	1						
31	*Acer rubrum*	1	2	2				
	Halesia carolina	1	4					
	Hamamelis virginiana	14						
	Magnolia fraseri	2						
	Nyssa sylvatica	18	5					
	Oxydendrum arboreum	1	1					
	Pinus pungens		8	2				
	Quercus prinus	6	3	5				
	Robinia pseudo-acacia		1					
32	*Acer rubrum*	2						
	Oxydendrum arboreum	2						
	Pinus pungens	5	12	5	5	1		
33	*Acer rubrum*	3	2	3				
	Castanea dentata	1						
	Hamamelis virginiana	14						
	Magnolia fraseri	8	1					
	Nyssa sylvatica	38	13					
	Oxydendrum arboreum		4					
	Pinus pungens	1	2					
	Quercus prinus		1					
	Robinia pseudo-acacia		2	1				
	Sassafras albidum		1					
34	*Acer rubrum*	1						
	Castanea dentata	1						
	Oxydendrum arboreum	12						
	Pinus pungens	72	5	5	2	2		

Plot No.	Taxa	Diameter Classes 1-3.5	3.6-7.5	7.6-10.5	10.6-13.5	13.6-16.5	16.6-19.5	19.6-22.6
35	*Acer rubrum*	10	1					
	Castanea dentata	2						
	Hamamelis virginiana	15						
	Magnolia fraseri	1						
	Nyssa sylvatica	20						
	Oxydendrum arboreum	2						
	Pinus pungens	24	6	2	1			
	Quercus prinus	1	3					
	Tsuga canadensis	1						
36	*Acer rubrum*	2						
	Nyssa sylvatica	8						
	Pinus pungens	56	23	1	2			
	Robinia pseudo-acacia	2						
37	*Acer rubrum*	2						
	Hamamelis virginiana	3						
	Nyssa sylvatica	10						
	Pinus pungens	40	29	1	1			
	Quercus prinus	2						
	Robinia pseudo-acacia	1						
38	*Acer rubrum*	1						
	Hamamelis virginiana	12						
	Pinus pungens	77	14	3	1			
39	*Acer rubrum*	7						
	Fagus grandifolia		1					
	Hamamelis virginiana	6						
	Nyssa sylvatica	22						
	Pinus pungens	34	44	2	2	1		

Plot No.	Taxa	Diameter Classes 1-3.5	3.6-7.5	7.6-10.5	10.6-13.5	13.6-16.5	16.6-19.5	19.6-22.6
40	Acer rubrum	2						
	Nyssa sylvatica	11						
	Oxydendrum arboreum	1						
	Pinus pungens	52	30	2	1			
	Quercus prinus	5						

APPENDIX C

SUMMARY OF SHRUB TAXA IN DIAMETER CLASSES BY PLOT

Plot No.	Taxa	Diameter Classes .1-.68	.69-1.26	1.27-1.84	1.85-2.42	2.43-3.00
1	Kalmia latifolia	3	9	2		
	Pieris floribunda	1				
	Rhododendron maximum	4	2	4	3	
2	Kalmia latifolia	10	14			
	Vaccinium sp.	29				
3	Kalmia latifolia	1				1
	Vaccinium sp.	7				
4	Kalmia latifolia	15	8		5	2
	Pieris floribunda	9	1			
	Rhododendron maximum	16			2	
	Vaccinium sp.	3	3			
5	Kalmia latifolia	17	14	7		
	Pieris floribunda	2			1	
6	Kalmia latifolia	16	4	6	3	
	Pieris floribunda	15				
	Vaccinium sp.	3				
7	Kalmia latifolia	15	9	1		
	Vaccinium sp.	30				
8	Kalmia latifolia	13	10		1	
	Rhododendron maximum	1	2	1		
9	Kalmia latifolia	42	13			
	Vaccinium sp.	21				
10	Kalmia latifolia	25	17	3		
	Vaccinium sp.	18				
11	Kalmia latifolia	11	17	2		
	Pieris floribunda	2	1		1	1

Plot No.	Taxa	Diameter Classes .1-.68	.69-1.26	1.27-1.84	1.85-2.42	2.43-3.00
12	Kalmia latifolia	27	20			
	Pieris floribunda	28	5	1		
	Vaccinium sp.	17				
13	Kalmia latifolia	27	3			
	Vaccinium sp.	25				
14	Kalmia latifolia	28	2			
	Vaccinium sp.	24				
15	Kalmia latifolia	12	3			
	Pieris floribunda	7	3	2	1	1
	Vaccinium sp.	18				
16	Kalmia latifolia	21	1			
	Pieris floribunda	40	4			
	Rhododendron maximum	1				
17	Kalmia latifolia	9	4			
	Pieris floribunda	29	5	1		
	Vaccinium sp.	26				
18	Kalmia latifolia	4	1			
	Pieris floribunda	10	2			
	Rhododendron maximum	13	3	1	4	1
19	Kalmia latifolia	33	7			
	Pieris floribunda	11	3	1		
	Vaccinium sp.	5				
20	Kalmia latifolia	13	8			
	Pieris floribunda	3				
	Vaccinium sp.	24				
21	Kalmia latifolia		6	1		
	Pieris floribunda	10	2	1	3	
	Rhododendron maximum	3				
22	Kalmia latifolia	9	5			
	Pieris floribunda	26	9			
	Vaccinium sp.	4				
23	Kalmia latifolia	15	7			
	Vaccinium sp.	21				

Plot No.	Taxa	Diameter Classes .1-.68	.69-1.26	1.27-1.84	1.85-2.42	2.43-3.00
24	*Kalmia latifolia*	52	3			
	Pieris floribunda	7	1			
	Vaccinium sp.	12				
25	*Kalmia latifolia*	6	7	2	1	
	Pieris floribunda	1		2	2	
	Vaccinium sp.	28				
26	*Kalmia latifolia*	3	12	2		
	Rhododendron maximum	6	1		1	1
27	*Kalmia latifolia*	10	2	2		
	Pieris floribunda	5				
	Vaccinium sp.	9				
28	*Kalmia latifolia*	1	14	4		
	Vaccinium sp.	7				
29	*Kalmia latifolia*	5	5	3		
	Pieris floribunda	3		1	2	
	Vaccinium sp.	1				
30	*Kalmia latifolia*	7	5	1	1	
	Rhododendron maximum	12	4			1
31	*Kalmia latifolia*	1	5	1		
	Vaccinium sp.	1				
32	*Kalmia latifolia*	9	12	3		
33	*Kalmia latifolia*	14	26	3		
34	*Kalmia latifolia*	8	11	3		1
	Vaccinium sp.	2				
35	*Kalmia latifolia*	37	7			
	Vaccinium sp.	32				
36	*Kalmia latifolia*	17	12			
	Pieris floribunda	7	3	2	1	
	Vaccinium sp.	5				
37	*Kalmia latifolia*	4	10	3		
	Pieris floribunda	8				

Plot No.	Taxa	Diameter Classes .1- .68	.69- 1.26	1.27- 1.84	1.85- 2.42	2.43- 3.00
38	*Kalmia latifolia*	22	48	5		
	Pieris floribunda	20	8	5	1	
39	*Kalmia latifolia*	46	18	1		
	Vaccinium sp.	17				
40	*Kalmia latifolia*	21	4	1		